NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3676

INVESTIGATION OF LATERAL CONTROL NEAR THE STALL

FLIGHT TESTS WITH HIGH-WING AND LOW-WING MONOPLANES OF VARIOUS CONFIGURATIONS

By Fred E. Weick and H. Norman Abramson

Agricultural and Mechanical College of Texas

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SUMMARY

This report, the second in a series dealing with the problem of control near the stall, presents the results of flight tests with several typical light aircraft. It has been found that, for all of the aircraft tested, adequate lateral control is available up to some critical angle of attack that is always within 2° of the angle of attack for maximum lift. The elevator deflection required to trim at this condition has been found, with power off and power on, for each of the aircraft tested, as well as the elevator deflection required to make a three-point landing.

Flight tests were made with one airplane having two different horizontal tail configurations in an attempt to provide an arrangement that would give near-optimum conditions with regard to the effect of power change on longitudinal trim near the stall. This attempt was successful with one of the configurations tested, so that under all of the conditions of power setting and center-of-gravity position tested the available elevator deflection was sufficient only to maintain the angle of attack at a point where lateral control remained adequate. The increase in minimum speed was negligible.

These results are intended to provide quantitative flight-test information which may be useful to designers in attempting to provide for adequate low-speed control and which may be correlated with analytical analyses as presented in the third and final report in this series (Technical Note 3677).

INTRODUCTION

This report presents the results of the second portion of an investigation into the possibilities of obtaining reliable lateral control at the lowest flight speeds of light airplanes. The first portion of the program was reported in reference 1.

This investigation was based upon the hypothesis that satisfactory rolling control is obtainable by a human pilot only if the lateral stability factor, damping in roll, is positive. Positive damping in roll is, in turn, dependent on the slope of the lift curve, where an increase in angle of attack is attended by an increase in lift. It then follows that, in order to retain sufficient rolling control under all conditions, the outboard elements of a wing must be prevented from stalling at the highest angles of attack maintainable.

Flight tests have shown that, when an airplane is in stalled flight and autorotative moments are present together with violently changing burbled flow, a pilot cannot maintain satisfactory lateral control even with special devices such as spoilers which will give ample rolling moments for control. The difficulty is that the autorotative moments build up so rapidly that the pilot cannot react quickly enough to maintain the airplane at the lateral attitude desired (ref. 2).

It is hoped that this entire investigation will provide the designer with quantitative design information from which the proper combination of variables may be selected to insure satisfactory control near the stall. This involves determining the highest angle of attack at which satisfactory lateral control can be maintained and comparing this angle of attack with that for the maximum lift coefficient. From the comparison an estimate can be made of any possible sacrifice of low-speed performance which might be entailed by limiting the up-elevator travel to the point where the critical angle of attack is the maximum that can be maintained.

In the first part of this investigation (ref. 1) flight tests were made with a typical light, high-wing monoplane. It was found that satisfactory lateral control occurred consistently, even under conditions simulating extremely gusty air, at angles of attack approximately 2° below that for the maximum lift coefficient (or the stall of the wing as a whole). This 2° margin was substantially the same both with full power and with the engine throttled and throughout the range of center-of-gravity locations tested. Supplementary tests were then made on the control at high angles of attack under actual gusty air conditions, on the possibility of entering spins, and on the amount of elevator control required for normal three-point landings. It was found that, with the original plain untwisted wing, attainment of the constant 2° margin below the stall required widely different elevator deflections for the range of power conditions and center-of-gravity locations tested. Also, none of these elevator deflections was high enough to produce a three-point landing.

There are two paths towards attainment of the reliable low-speed control conditions sought. One of these is increasing the angle of attack at which damping in roll is effective to a point beyond the highest angle of attack that is required in steady flight or in landing.

This path was followed in the first part of the investigation by testing the airplane with three different amounts of washout and with five different lengths of leading-edge slots. Each method was successful only for power-off flight and for a narrow range of center-of-gravity locations.

The other path involves the reduction of the scatter of the maximum elevator deflections required with the various power conditions and center-of-gravity locations. The change of trim due to power is influenced by such factors as the position and inclination of the thrust axis and the influence of the slipstream on the tail surfaces with the elevator deflected. This path was followed in the present, or second, portion of the investigation in which additional airplane configurations were tested. The airplanes included another high-wing monoplane, two low-wing monoplanes with straight wings, and a low-wing monoplane having a tapered wing with both geometric washout and change of airfoil section along the span.

One airplane was tested with different horizontal tail configurations in an attempt to provide an arrangement that would give near-optimum conditions with regard to the effect of power change on longitudinal trim near the stall. These results are intended to provide quantitative flight-test information which may be correlated with a numerical analysis of the effects of changes in various design variables on longitudinal trim characteristics as presented in the third and final report of this series (ref. 3).

The authors wish to thank Mr. G. A. Roth and Mr. R. L. Hamm for their assistance with various portions of the investigation. This work was conducted at the Aircraft Research Center of the Texas Engineering Experiment Station, Texas Agricultural and Mechanical College System, under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

APPARATUS

<u>Test airplanes</u>.- The airplanes used in the present tests are shown in figures 1 to 8, and descriptive characteristics are listed in tables I to IV.

The Interstate S-1A is a tandem high-wing monoplane of general form somewhat similar to the side-by-side Taylorcraft BC-12 used in the first part of the program (ref. 1).

The Fairchild PT-19 is a tandem low-wing monoplane having a tapered plan form. The tip chord is 0.6 of the root chord. The airfoil section changes from the NACA 2416 at the root to the NACA 4409 at the tip. In spite of the higher camber at the tip, an examination of the airfoil lift versus angle-of-attack characteristics indicates no appreciable increase in angle of attack for the stall from the section change. Measurements of the test airplane wing showed a geometric washout of 2.7° from the wing root just outside the fuselage fillet to the outer end of the aileron.

The Ag-1 is an experimental agricultural airplane having a low untapered wing. The airfoil section is the NACA 64021, slightly modified. A full-span slotted flap is used, the center panel having a maximum deflection of 40° and the outer panels, 25°. The lateral-control system is unique in that slot-lip ailerons are linked directly to the outer panel flaps, and both are used together to give rolling control. With full-right control deflection the right flap aileron is up 5° from the neutral position and the right slot-lip aileron is up 26°, while the left flap aileron is down 8° and the left slot-lip aileron is down 6°. Thus, the slot-lip ailerons have an extreme differential movement, whereas the flap ailerons have a slight but inverted differential movement. The neutral position of the slot-lip aileron is up 5° from the wing contour with all flap positions, whereas the neutral position of the flap ailerons is the same as the outer-panel-flap setting.

The Ercoupe is a side-by-side airplane with a low untapered wing and a tricycle-type landing gear. The control system of this airplane is two-control inasmuch as rudder action is linked to the ailerons. Two different horizontal tail configurations were used on this airplane, as shown in figures 8 and 9.

Instrumentation.- The instrumentation was substantially the same as that employed in the first portion of the program (ref. 1).

TEST PROCEDURE

Following the various exploratory tests made in the first part of the investigation (ref. 1), it was decided that the data required in this portion could be obtained satisfactorily from the following types of tests.

Determination of maximum angle of attack below stall at which lateral control is still available in gusty air.- As explained in reference 1, the test for satisfactory lateral control was made to simulate gusty air conditions which are more critical than still air conditions. The maneuver was started from steady straight flight and the elevator was maintained in a fixed position throughout the entire maneuver. In order to simulate the encountering of a severe gust, the ailerons were deflected abruptly and held full over until an angle of bank of approximately 10° was reached.

At this point the maximum rate of roll was ordinarily obtained. As the roll angle of approximately 10° was reached, the ailerons were abruptly reversed and the reaction was noted.

The procedure was repeated with the elevator maintained in a series of fixed positions, until the angle of attack nearest the stall was found at which satisfactory recovery resulted from the aileron reversal.

A secondary effect results from the yaw accompanying the rolling action, since the combination of yaw and dihedral is responsible for further increment of angle which functions to advance the stall. On this account the maneuvers were repeated starting with approximately 5° of yaw, which was taken to represent the asymmetry likely to be produced by an inexpert pilot.

Longitudinal trim.- The minimum amount of elevator angle required to make smooth three-point landings (landings with tail wheel and main wheels touching the ground simultaneously) was found by flight trials.

The elevator deflection required to trim at various speeds, with power off and power on, was also determined. The Ercoupe airplane was tested using two different horizontal tail configurations in an attempt to provide an arrangement that would result in little or no change in the elevator deflection required to trim, with power off and power on.

RESULTS AND DISCUSSION

Maximum angle of attack below stall at which lateral control is still available.- As was brought out in reference 1, the critical angle of attack for satisfactory roll recovery is taken to be the entry angle of attack in steady flight, with the elevator and rudder held fixed throughout, from which the ailerons can be abruptly and fully deflected until the maximum rate of roll is reached and then abruptly reversed and the airplane returned to level flight, all without changing the attitude in a nose-down direction by more than 10°.

All of the aileron tests to find the critical angle of attack for satisfactory lateral control were repeated with the rudder held over to a constant deflection which resulted in what the pilot judged was approximately 5° of yaw in the preliminary steady portion of the maneuver. The results were erratic, however, compared with those in the Taylorcraft tests of reference 1 in which a yawmeter was used. The results presented are therefore those of all of the tests starting with what the pilot considered straight flight.

The critical angles of attack α_{cr} are presented in table V for all of the airplanes tested and for the unmodified Taylorcraft of reference 1.

It will be noted that, for each condition of each airplane tested, satisfactory lateral control was obtained up to a critical angle of attack that was less than 2° below the stall.

The difference between the stalling speed and the speed at the critical angle of attack ranged from 0 to 2.5 mph. Since these values of angle-of-attack margin α_{mar} and speed difference cover each of the conditions tested for all four of the airplanes investigated, they can probably be considered generally applicable to most airplanes in the light-airplane category.

The small sacrifice in minimum speed would appear to be well worth while in order to insure satisfactory lateral control at low speed. The problem from this point on is to arrange the airplane so that a single maximum elevator deflection will result in approximately the critical angle of attack for satisfactory lateral control under all conditions of power, flap setting, and loading.

Critical elevator deflections.- The elevator deflections required to maintain each critical angle of attack for satisfactory lateral control are given in table VI for each airplane and condition tested. Also listed are the elevator deflections required to stall the airplanes and those required to make three-point landings with power off.

It is apparent from table VI that the Interstate S-1A airplane, like the Taylorcraft airplane of reference 1, could not be used satisfactorily with a single limitation of the up-elevator travel to insure satisfactory lateral control at low speed. If the up travel were limited to 5.50° for the case of rearward center of gravity with power on, the entire low-speed end of the operating range would be sacrificed in the case of forward center of gravity with power off, for the latter case required 17.5° more up-elevator deflection.

With the Interstate airplane it was possible, however, to make three-point landings using no more up-elevator deflection than was necessary to maintain the critical angle of attack for satisfactory roll control. This condition was not obtained with the Taylorcraft except when the airplane was modified by a large amount of washout or by leading-edge slots.

If the Interstate airplane could be modified so that the longitudinal trim would be the same with power full on as it is with power off and the center-of-gravity travel could be made small enough, a single maximum elevator deflection could be found that would be acceptable from the performance standpoint and still insure satisfactory lateral control at the highest angles of attack that could be maintained in flight.

It appears that low-wing monoplanes should have an advantage with respect to reducing the effect of power change on longitudinal trim, because of the relatively high position of the thrust axis relative to the drag. With a low-wing monoplane the high thrust gives a pitching moment tending to nose the airplane down and acting opposite to the tail-depressing pitching moment caused by the propeller slipstream. However, the results of analytical studies (ref. 3) have shown that one of the most important design parameters is the location of the horizontal tail with respect to the wing wake. The location of the elevator with respect to the slipstream was also shown to be an extremely important factor in reducing the effect of power change on longitudinal trim. These conclusions are also confirmed by results of flight tests with the Ercoupe airplane, which will be discussed later.

The results of the tests on the Fairchild PT-19 and the Ag-1 low-wing monoplanes can be compared with those for the high-wing monoplanes in table VI. For the PT-19 airplane with rearward center of gravity and flaps up, a 4.6° difference in elevator deflection between the power-off and the power-on conditions was required to maintain the critical angle of attack for satisfactory lateral control. This difference in elevator deflection was substantially greater with the Interstate high-wing monoplane, but it was only slightly higher with the Taylorcraft high-wing monoplane of reference 1.

With the flaps full down on the Fairchild PT-19 airplane the difference in elevator settings for the critical angles of attack with power on and power off was somewhat less, being 3.8° for the forward center-of-gravity condition and zero (or ideal for the present purpose) for the rearward center-of-gravity condition.

Although the PT-19 airplane with the flap down has the ideal characteristic of the same elevator deflection for the critical angles of attack for satisfactory lateral control with power on and with power off, it has the disadvantage of requiring an elevator deflection 9° greater in order to make a three-point landing. In the flaps-up condition the extra elevator deflection required for a three-point landing is less, being 2.5° with the center of gravity at 30 percent mean aerodynamic chord and 4.3° with the center of gravity at 25 percent mean aerodynamic chord.

With the Ag-1 in the power-off, flaps-up condition, satisfactory lateral control was obtained up to the highest elevator deflection available, -10.5°. Throughout the lowest 5 mph of the speed range, however, tail buffeting and slight irregularities in the longitudinal flight path occurred if the speed was held approximately constant. If the speed was gradually reduced as in a normal landing, only a very slight evidence of buffeting occurred and a lower airspeed was reached (see footnote to table V). Apparently, in this condition the smooth air flow broke down in the juncture between the fuselage and the wing, and the lessened downwash in the center reduced the down load on the tail and required greater elevator deflection. At any rate, in the power-off, flaps-up condition, only a 6.5° up-elevator deflection was necessary to make a three-point landing, whereas the lateral control was satisfactory up to an elevator deflection at least 4° higher, which in itself was very satisfactory.

With power on, however, the critical angle of attack for satisfactory lateral control was obtained with an up-elevator deflection of only 1.0°, or 5.5° less than the deflection which gave satisfactory results with power off. With the flaps-down condition, this difference in elevator deflections required for the critical angles of attack for satisfactory lateral control, with power on and power off, was found to be 4.5°.

The horizontal stabilizer of the Ag-1 airplane is adjustable for speed trim, and it is also linked to the flap. When the flap is depressed, the leading edge of the stabilizer moves down also in order to compensate for the change in pitching moment due to the flap. It appears that it should be possible to adjust the stabilizer movement relative to the flap so that the same elevator deflection would result in the critical angle of attack for satisfactory roll control for all flap positions. It might be difficult, however, to get satisfactory speed trim at the same time.

In general, as was brought out in reference 1, a larger up-elevator deflection is required to attain the angle of attack required for a three-point landing than is required for the same angle of attack at an altitude clear of ground effect. An examination of table VI shows that this effect is much more pronounced for the cases with flaps deflected than for the others, probably because the ground effect was greater where the downwash was greater.

In two cases, the Interstate S-1A and the Ag-1 with flaps up, three-point landings could be made without exceeding the elevator deflection required to maintain the critical angle of attack for satisfactory lateral control.

Margin below stall at which airplanes would not spin.- Early tests showed that, if an airplane had insufficient up-elevator travel for it to be put into a spin, the ailerons were effective at the highest angle of attack and lowest speed that could be maintained. In the program of reference 1 this spin condition was investigated for comparison with the critical angles of attack found in the roll-recovery tests. In the present, or second, portion of the investigation the spin trials were made with the Interstate S-1A and the Ag-1 airplanes but not with the Fairchild PT-19 because of the age of the wood wing structure.

With the Interstate airplane power-off spins could be obtained with more than 15° of up elevator with the forward center-of-gravity condition and more than 6° with the rearward center-of-gravity condition. These values are both about 8° lower than the elevator deflections giving satisfactory lateral control under the simulated gusty air conditions, a condition which may possibly be explained by the powerful rudder of this airplane.

The Ag-1 airplane, with the center-of-gravity condition tested, could not be made to spin under any condition of power or flap setting.

Longitudinal trim change with application of power.- The test results discussed thus far have shown that there is a critical angle of attack, within 2° of the angle for maximum lift, below which adequate lateral control is available. However, the attainment of this critical angle of attack required widely different elevator deflections for power-on and power-off flight and for different center-of-gravity locations. Therefore, the Ercoupe airplane was tested with two different horizontal tail configurations in an attempt to provide an arrangement that would result in a negligible change in the elevator deflection required for trim with change in power setting.

The two tail configurations tested were both modifications of the original tail and are shown in the photographs of figure 8; a comparison of the three tails is shown in figure 9. It will readily be observed that the modifications were attempts to move the elevator out of the region of influence of the slipstream; the elevator areas in the two cases differed considerably.

Results of flight tests with modified tail 1 are given in figure 10. The first plot (fig. 10(a)) shows true indicated airspeed versus elevator deflection for power-on and power-off conditions. At a true indicated airspeed of about 49 mph a partial stall was encountered in the power-off condition. Flight observations of tufts placed on the wing surface showed that separation was occurring over the rear portion of the wing near the fuselage. By modifying the elevator control linkage to increase the upward deflection available, data were obtained in the power-off condition through a portion of this range. The wing angle-of-attack variation with elevator deflection is shown in figure 10(b); it is readily seen that rather high angles of attack were attained in the power-off condition. Finally, the third plot (fig. 10(c)) shows lift coefficient versus angle of attack; the region where partial loss of lift occurs in power-off flight is very clear.

A few tests were also made with rather large fillets installed at the wing-fuselage juncture (see fig. 8). The standard Ercoupe sharp leading edges adjacent to the fuselage were eliminated for these tests. The fillets were installed in an attempt to eliminate the burbled flow in order that data might be procured in the lowest speed region attainable. The only noticeable effect of the fillets was to increase the maximum lift coefficient and the angle of attack for maximum lift in the power-off condition.

The results of tests performed with modified tail 2 are given in figure 11. As with tail 1, tests were conducted with the large fillets installed. Again it was found that a slightly higher lift coefficient in the power-off condition was attained.

It will be noted from the plots of figure 11 that, although the minimum speed with power on was the same as that for tail 1 and although the minimum speed with power off was about 2.5 mph lower that that for tail 1, the maximum attainable angle of attack was less and the region of partial stall (power off) was not attained. This is explained by the fact that the stabilizer was large compared with the elevators, and even a 30° elevator deflection did not stall the airplane.

In tests with tail 2, the center of gravity was shifted rearward to the rearmost practical location, or until the weight of the pilot standing on the wing root trailing edge was sufficient to tend to lift the nose wheel from the ground; the precise location of the center of gravity was 25 percent mean aerodynamic chord, or 1 percent beyond the rearmost position approved for this airplane by the Civil Aeronautics Administration. Even in this condition for which the center of gravity was more rearward than can be obtained by any normal manner of loading the airplane, smooth flight with ample lateral control was obtained at minimum speed with the elevator control full back, both with power off and with power full on.

Other flight trials of this configuration were made with the center of gravity as far forward as 18 percent mean aerodynamic chord, and no substantial loss in the minimum-speed performance was found.

Because of the difference in elevator area for the two tail configurations it is difficult to compare the results directly. However, the principal purpose here is to study the conditions whereby a minimum difference in trim, with power on and power off, is attained. Considering tail 1, at $\delta_e = -15^{\circ}$ the difference (with power on and power off) in true indicated airspeed is about 2.2 mph, corresponding to an average angle of attack (with power on and power off) of 15.7. At the same average angle of attack for tail 2, the change in true indicated airspeed is only 1.5 mph.

At $\delta_e = -19^{\circ}$ for tail 1 the difference in true indicated airspeed is about 6.5 mph for an average angle of attack of 18.5°; for tail 2 at this average angle of attack the difference in true indicated airspeed remained about 1.5 mph. The wide discrepancy between results for the two tails in the latter case was due, of course, to the fact that for tail 1 the wing was partly stalled.

It might be concluded on the basis of the data presented that tail 2 offers substantial advantages over tail 1 as regards longitudinal trim characteristics. First of all, it is clear that, although the elevator deflections for tail 2 are much greater than those for tail 1, the airplane was not brought into a partial stall because of the loss in effectiveness of these relatively wide chord short-span elevators at large deflections. Therefore, even with the most rearward center-of-gravity position attainable, the difference in elevator deflection required to trim, with power off and power on, was less than 2°.

However, if one were to limit the elevator deflection of tail 1 to $\delta_e = -15^{\circ}$, then it is seen that substantially equivalent results could be attained but with about a 2-mph increase in minimum speed. Such a small sacrifice in minimum speed may very well be negligible in many instances, particularly with a tricycle-gear airplane.

Thus it is seen that the desired condition of minimum change in elevator deflection required to trim, with power off and power on, may be attained in two different ways: either by mechanically limiting the elevator deflection in a desired manner (as discussed in the preceding paragraph) or by providing an elevator configuration which results in the desired conditions by reduction in effectiveness at large deflections (as was found for tail 2).

Consequently, it is the maximum tail-depressing power that must be restricted and not necessarily the up-elevator deflection. This may be accomplished, as demonstrated by the flight-test results just discussed, without obvious restriction of the elevator deflection by employing an elevator of relatively small area. Thus, in the region near the critical angle of attack, rather large elevator deflections will occur; however, the tail effectiveness is rather insensitive at these large elevator deflections and therefore the maximum usable deflection is not so critical and is not regarded as "limited." This procedure does, however, require a rather careful proportioning of areas between the elevator and horizontal stabilizer; the analytical methods of the final report in this series (ref. 3) are useful in this regard.

It is highly important to state that adequate lateral control was available for the Ercoupe airplane in all conditions tested and with both tail configurations. Even in the case of partially stalled power-off flight with tail 1, lateral control was adequate, for the burbled flow was confined to the central portion of the wing.

CONCLUDING REMARKS

Flight tests were made with several typical light airplanes to investigate possibilities for obtaining reliable lateral control at low flight speeds. It is noteworthy that for each condition (amount of power, flap setting, and center-of-gravity location) of each airplane tested, satisfactory lateral control was obtained up to a critical angle of attack that was in each case within 2° of the angle of attack at which the airplane stalled. This value, less than 2°, can probably be considered applicable to most airplanes in the light-airplane category.

In many cases a maximum elevator deflection providing an angle of attack in steady flight that is 2° below that for the stall will also be insufficient to enable the airplane to be spun, but in some cases a smaller maximum elevator deflection would be required to eliminate the possibility of spinning.

The elevator deflection required for maintaining the critical angle of attack for satisfactory lateral control varies so greatly with differences in configuration, power, and center-of-gravity location that further detailed study of the effects of these factors is necessary if the results are generally to be quantitatively useful in airplane design. It is to be emphasized, however, that the desired conditions were obtained for one airplane by modification of the horizontal tail. It was found that the critical angle of attack could be maintained for power-on and power-off flight with a single maximum elevator deflection and that a negligible loss of low-speed performance occurred over a larger range of center-of-gravity locations than is ordinarily required for the airplane (18 to 25 percent mean aerodynamic chord). Although this is a smaller range of center-of-gravity positions than is needed in some airplanes, it is ample for the airplane tested because all variable loads (occupants, fuel, and baggage) are located near the center of gravity.

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TABLE I.- DIMENSIONAL CHARACTERISTICS

OF INTERSTATE S-1A AIRPLANE

Wing type	Straight high-wing, strut-braced
Landing gear	Fixed
Engine	Four-cylinder, horizontally opposed
Rated power, hp	65
Normal gross weight, lb	1,250
Propeller diameter, in.	72
Number of blades	2
Wing loading, lb/sq ft	7.2
Power loading, lb/hp	19.2
Wing airfoil section	NACA 23012
Wing plan form	Zero taper with rounded tips
Wing area including fuselage, sq ft	174
Wing span, ft	35.5
Mean aerodynamic chord, ft	4.9
Aspect ratio	7.25
Flap	None
Aileron type	Frise
Aileron area (each), sq ft	9
Aileron deflection, deg	±20
Stabilizer area, sq ft	13.1
Elevator area, sq ft	9.8
Elevator deflection, deg	28 up, 33 down
Elevator trim-tab deflection, deg	21 down
Fin area, sq ft	8.0
Rudder area, sq ft	8
Rudder deflection, deg	±31
Type of cockpit control	Stick

TABLE II.- DIMENSIONAL CHARACTERISTICS

OF FAIRCHILD PT-19 AIRPLANE

Wing type	Tapered low-wing, cantilever
Landing gear	Fixed
Engine	Six-cylinder, inverted
Rated power, hp	175
Normal gross weight, lb	2,450
Propeller diameter, in.	86
Number of blades	2
Wing loading, lb/sq ft	11.2
Power loading, lb/hp	14
Wing airfoil section	NACA 2416 at root varying to NACA 4409 at tip
Geometrical washout, deg	2.7
Wing plan form	Tapered, tip chord 0.6 of root chord
Wing area including fuselage, sq ft	218
Wing span, ft	36
Mean aerodynamic chord, ft	5.79
Aspect ratio	5.95
Flap	Balanced split flap
Aileron type, sq ft	Frise
Aileron area (each), deg	8.3
Aileron deflection	27 up, 15 down
Stabilizer area, sq ft	26.7
Elevator area, sq ft	13.2
Elevator deflection, deg	29 up, 29 down
Elevator trim-tab deflection, deg	21 down
Fin area, sq ft	6.9
Rudder area, sq ft	14.5
Rudder deflection, deg	31
Type of cockpit control	Stick

TABLE III.- DIMENSIONAL CHARACTERISTICS OF Ag-1 AIRPLANE

Wing type	Straight low-wing, cantilever
Landing gear	Fixed
Engine	Six-cylinder, horizontally opposed
Rated power, hp	225
Normal gross weight, lb	3,400
Gross weight as tested, lb	Approx. 2,700
Propeller diameter, in.	90
Number of blades	2
Normal wing loading, lb/sq ft	11.7
Normal power loading, lb/hp	15.1
Wing airfoil section	NACA 64021 modified
Wing plan form	Zero taper with partially rounded tips
Wing area including fuselage, sq ft	290
Wing span, ft	39.8
Mean aerodynamic chord, ft	7.5
Aspect ratio	5.5
Flap	Full-span slotted
Maximum flap deflection, deg	
Center panel	40
Outer panels	25
Aileron type	Combination flap and slot-lip ailerons
Aileron area (each), sq ft	
Flap	25
Slot-lip	9.7
Aileron deflections, deg	
Flap	5 up, 8 down
Slot-lip	26 up, 6 down
Stabilizer area, sq ft	33.3
Elevator area, sq ft	20.2
Elevator deflection, deg	10 up, 25 down
Adjustable stabilizer deflection, deg	3 up, 7 down
Fin area, sq ft	10.3
Rudder, sq ft	12.1
Rudder deflection, deg	±25
Type of cockpit control	Stick

TABLE IV.- DIMENSIONAL CHARACTERISTICS OF ERCOUPE AIRPLANE

Wing type	Straight low-wing, cantilever
Landing gear	Fixed, tricycle
Engine	Four-cylinder, horizontally opposed
Rated power, hp	85
Normal gross weight, lb	1,400
Propeller diameter, in.	73
Number of blades	2
Wing loading, lb/sq ft	9.8
Power loading, lb/hp	16.5
Wing airfoil section	NACA 43013
Wing plan form	Zero taper with rounded tips
Wing area including fuselage, sq ft	142.5
Wing span, ft	30
Mean aerodynamic chord, ft	4.76
Aspect ratio	6.3
Flap	None
Aileron type	Extreme differential control
Aileron area (each), sq ft	9.3
Maximum aileron deflection, deg	40 up, 10 down
Stabilizer area, sq ft	
Original tail	10.2
Modified tail 1	10.2
Modified tail 2	23.9
Elevator area, sq ft	
Original tail	9.2
Modified tail 1	7.7
Modified tail 2	5.2
Fin area (each), sq ft	
Original and modified tail 1	1.7
Modified tail 2	4.7
Rudder area (each), sq ft	
Original and modified tail 1	2.9
Modified tail 2	2.9
Type of cockpit control	Wheel

TABLE V.- CRITICAL ANGLES OF ATTACK FOR SATISFACTORY LATERAL CONTROL AND CORRESPONDING AIRSPEEDS

Configuration					Angles of attack, deg			True indicated airspeeds, mph		
Airplane	Gross wt., lb	Center of gravity, % M.A.C.	Flaps	Power	α_{cr}	α_{stall}	α_{mar}	At α_{cr}	At stall	Speed difference
Taylorcraft, zero washout (ref. 1)	1,050	27	None	On	15.7	17.0	1.3	41.4	40.2	1.2
		32	None	Off	15.8	17.0	1.2	42.0	41.2	.8
Interstate S-1A	1,080	21	None	On	15.0	16.0	1.0	37.0	36.0	1.0
		21	None	Off	13.0	14.0	1.0	41.5	40.5	1.0
		29	None	On	15.0	16.0	1.0	36.0	35.0	1.0
		29	None	Off	14.0	15.0	1.0	39.5	39.0	.5
Fairchild PT-19	2,250	25	Up	On	16.8	16.8	0	49.8	48.0	1.8
		25	Up	Off	16.1	16.8	.7	56.8	55.3	1.5
		25	Down	On	17.4	18.0	.6	43.5	42.0	1.5
		25	Down	Off	13.7	14.4	.7	50.5	49.0	1.5
	2,470	30	Up	On	16.1	18.0	1.9	52.0	51.0	1.0
		30	Up	Off	15.3	16.1	.8	59.2	58.7	.5
		30	Down	On	16.8	18.0	1.2	46.5	45.0	1.5
		30	Down	Off	13.0	14.4	1.4	51.6	51.0	.6
Ag-1	2,700	25	Up	On	14.5	16.0	1.5	44.8	42.6	2.2
		25	Up	[a]Off	[a]17.5	17.5	[a]0	[a]50 to 55	[a]50	[a]0
		25	Down	On	17.0	19.0	2.0	33.5	31.0	2.5
		25	Down	Off	13.0	14.5	1.5	40.3	38.6	1.7

[a]Tail buffeting with slight irregularities in the longitudinal flight path occurred at angles of attack above 13° and airspeeds below 55 mph, but lateral control was satisfactory at the highest angle of attack maintainable. If the speed was reduced at altitude as in a normal landing, the true indicated airspeed went down to 42 mph before the airplane stalled. In that case only slight evidence of buffeting occurred as the stall was approached.

TABLE VI.- SUMMARY OF CRITICAL ELEVATOR DEFLECTIONS

Configuration				Elevator deflections, deg, for - (a)					
Airplane	Gross wt., lb	Center of gravity, % M.A.C.	Flaps	α_{cr} for satisfactory lateral control: Power on	α_{cr} for satisfactory lateral control: Power off	α_{cr} for satisfactory lateral control: Difference	Stall: Power on	Stall: Power off	Three-point landing, power off
Taylorcraft, zero washout (ref. 1)	1,050	27	None	-3.8	-9.5	5.7			-14.1
		32	None	+1.9	-2.7	4.6			-9.5
Interstate S-1A	1,080	21	None	-9.6	-23.0	13.4	-11.2	-25.0	-23.0
		29	None	-5.5	-13.4	7.9	-7.0	-15.0	-10.0
Fairchild PT-19	2,250	25	Up	-15.2	-19.3	4.1	-19.3	-23.6	-23.6
		25	Down	-11.4	-15.2	3.8	-12.7	-16.5	-23.6
		30	Up	-5.6	-10.2	4.6	-6.7	-11.4	-12.7
		30	Down	-3.5	-3.5	0	-4.6	-4.6	-12.7
Ag-1	2,700	25	Up	-1.0	[b]-10.5	9.5	-2.5	[b]-6.5	-6.5
		25	Down	+3.5	-1.0	4.5	-1.0	-2.0	[c]-13

[a]Elevator deflections: (-) up, (+) down.

[b]See footnote for table V.

[c]Obtained by slight extrapolation because actual three-point landings were not quite achieved.

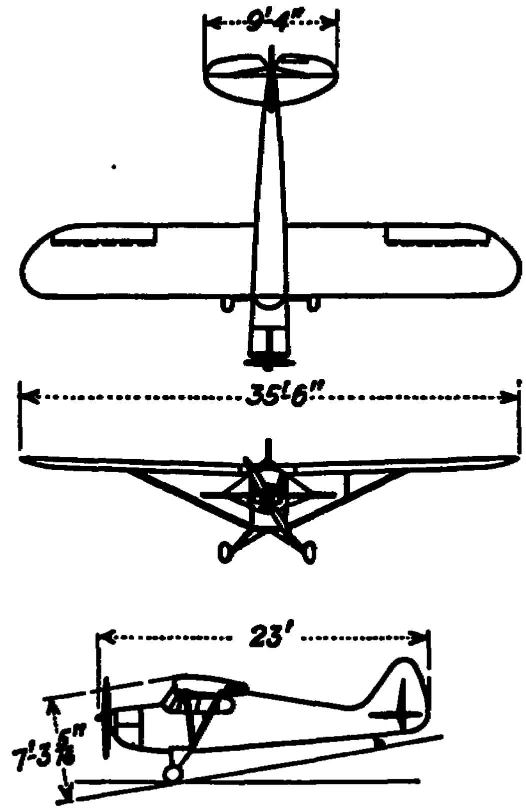


Figure 1.- Three-view drawing of Interstate S-1A airplane.

L-90564

Figure 2.- View of Interstate S-1A airplane.

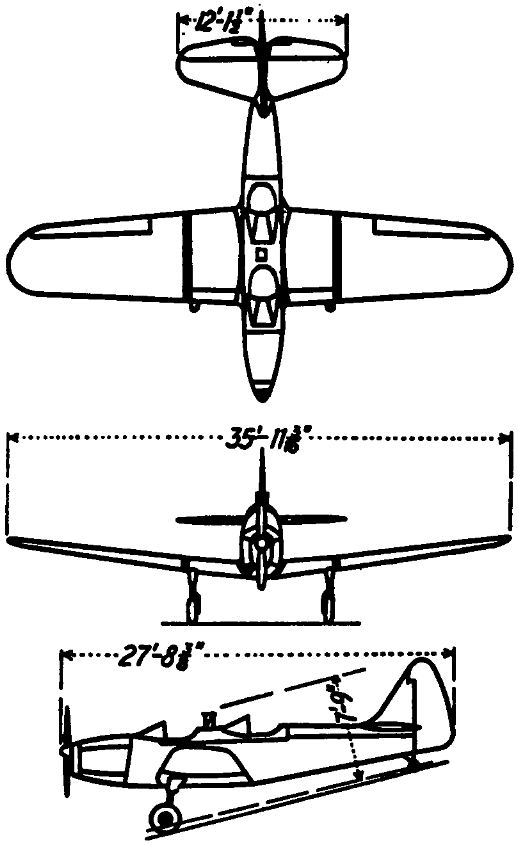
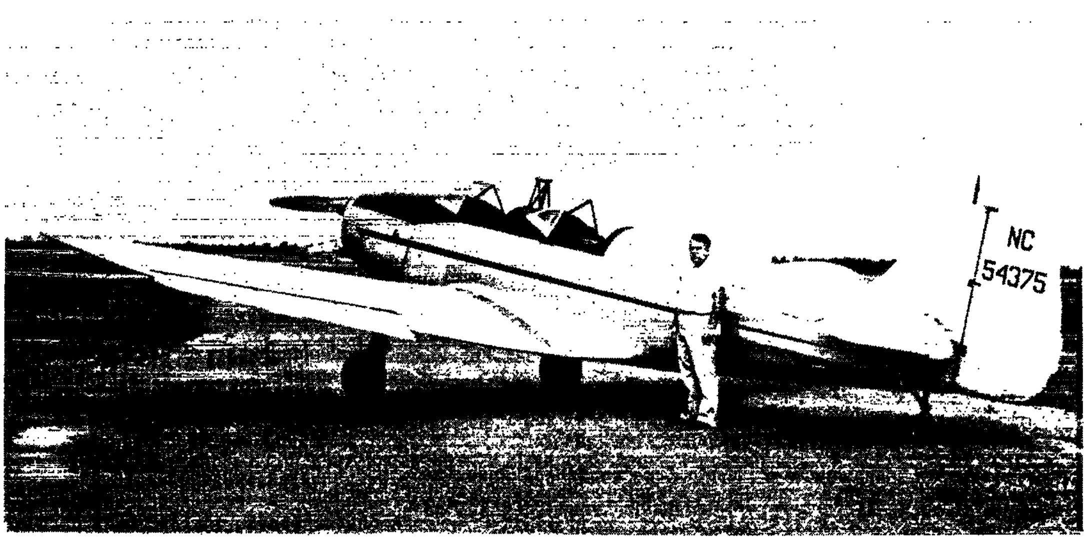


Figure 3.- Three-view drawing of Fairchild PT-19 airplane.



L-90565

Figure 4.- View of Fairchild PT-19 airplane.

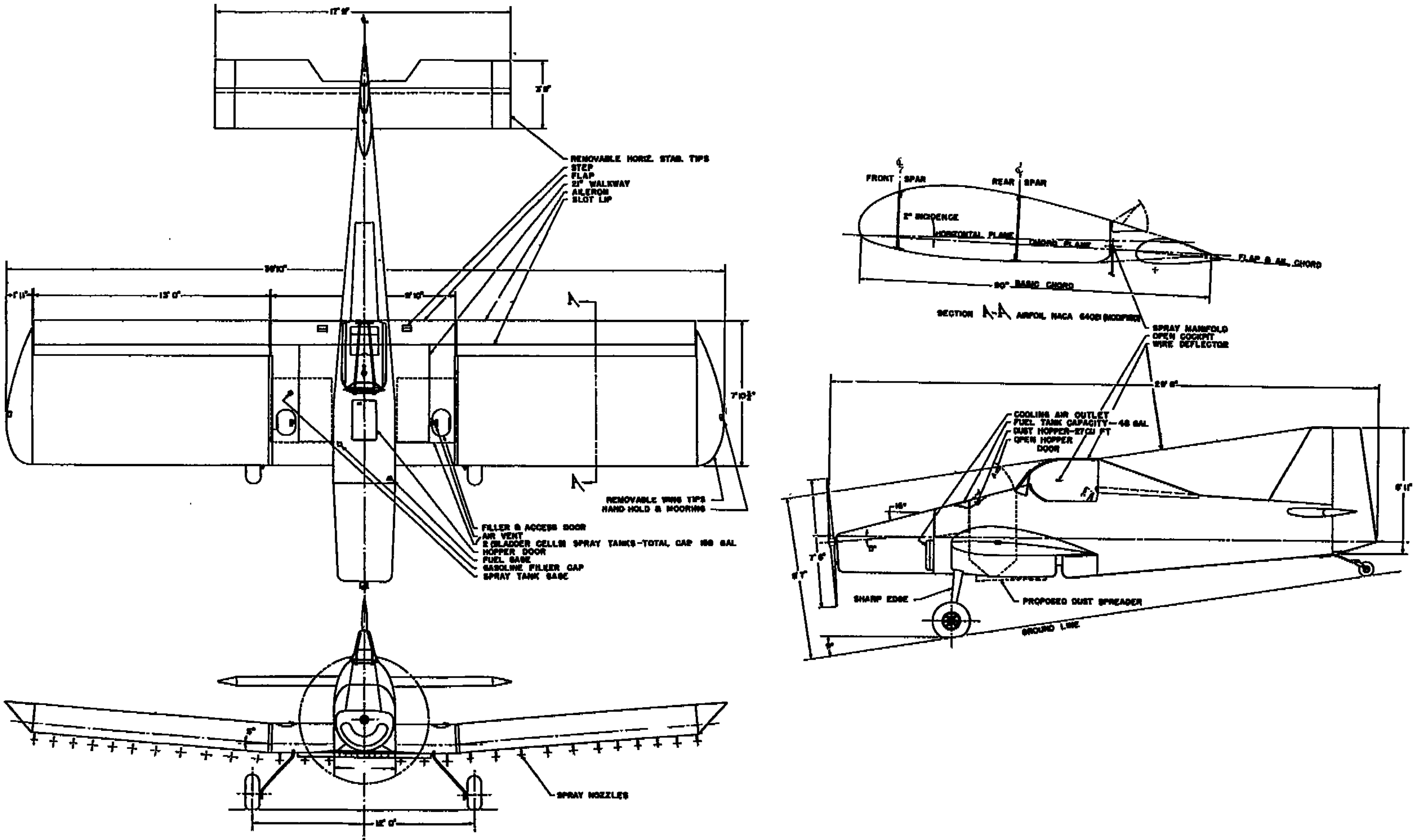
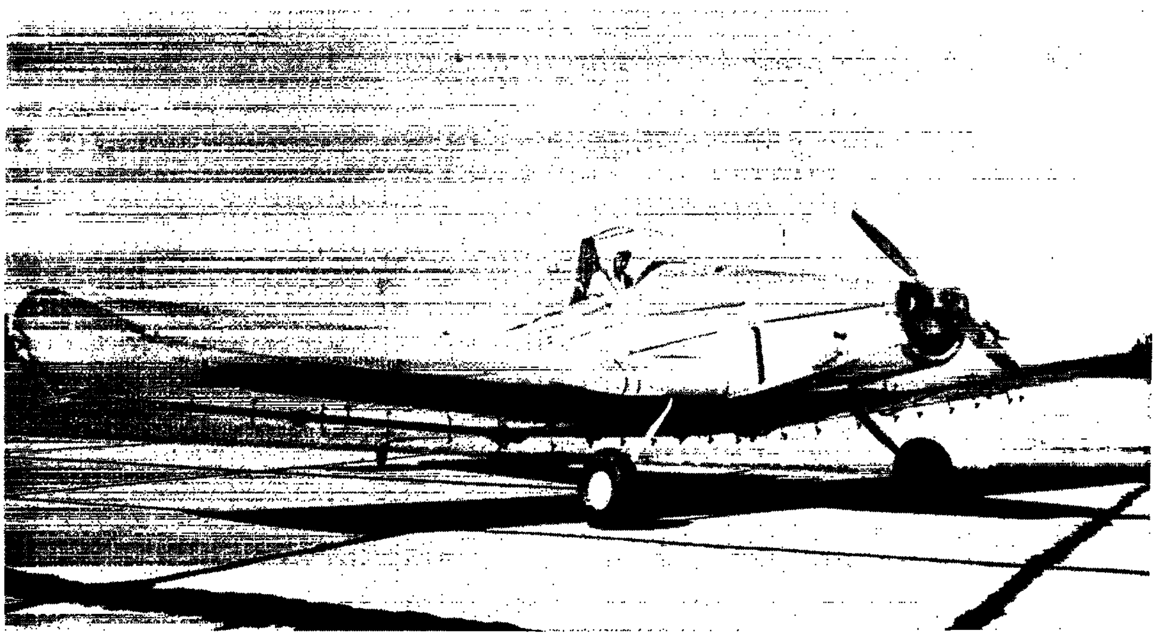


Figure 5.- Three-view drawing of Ag-1 airplane.



L-90566

Figure 6.- View of Ag-1 airplane.

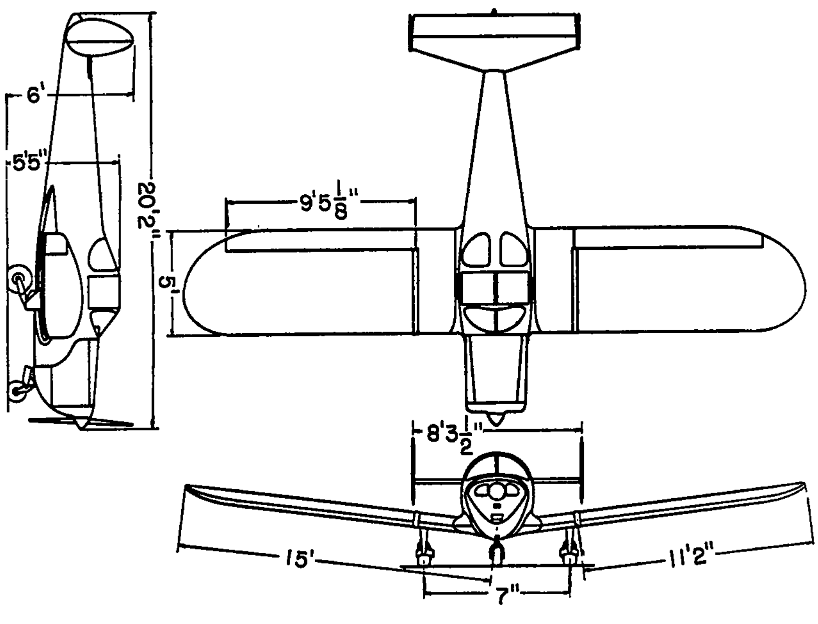
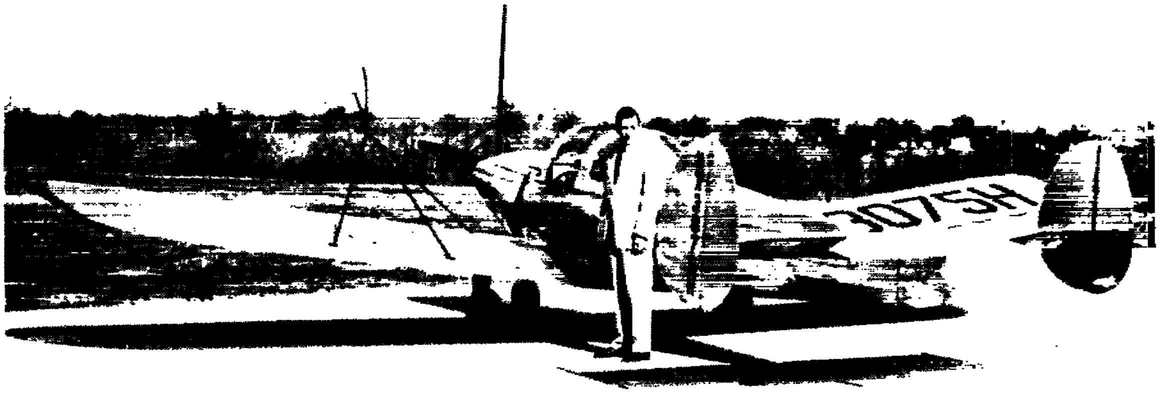
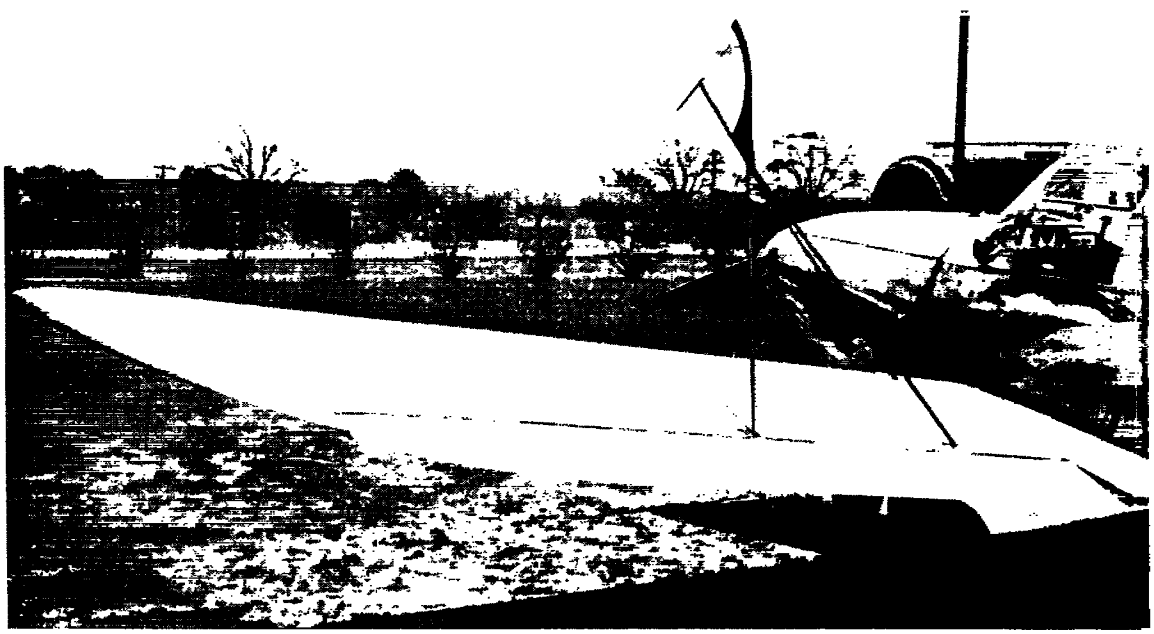


Figure 7.- Three-view drawing of Ercoupe airplane (original tail).

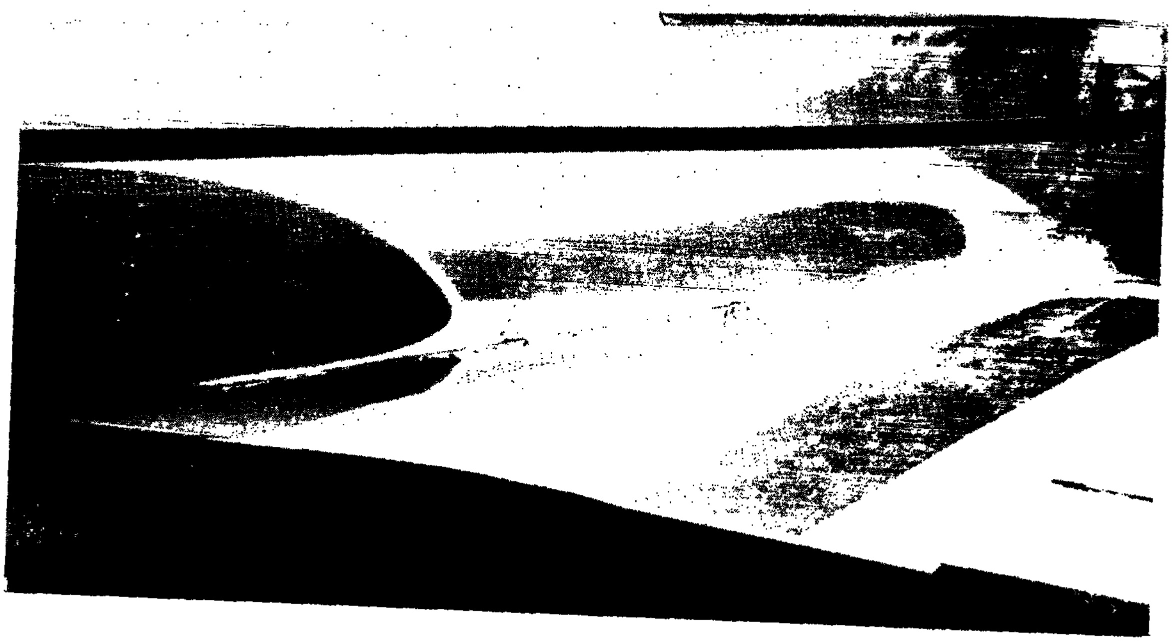


(a) View showing modified tail 2. L-90567



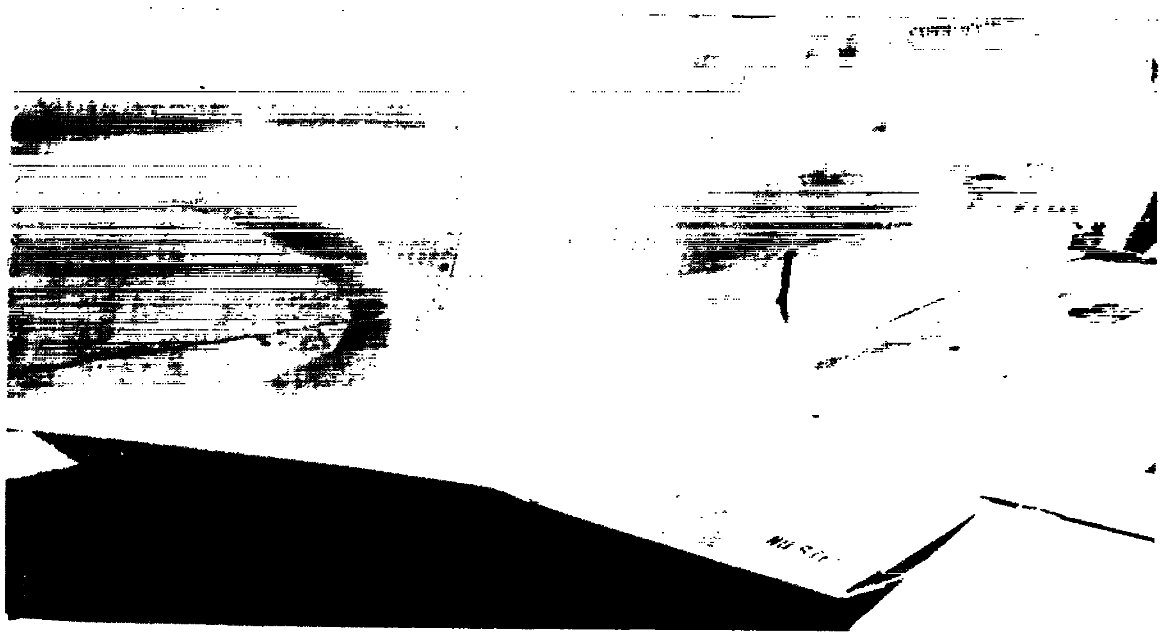
L-90568
(b) View showing angle-of-attack indicator and tufts.

Figure 8.- Ercoupe airplane.

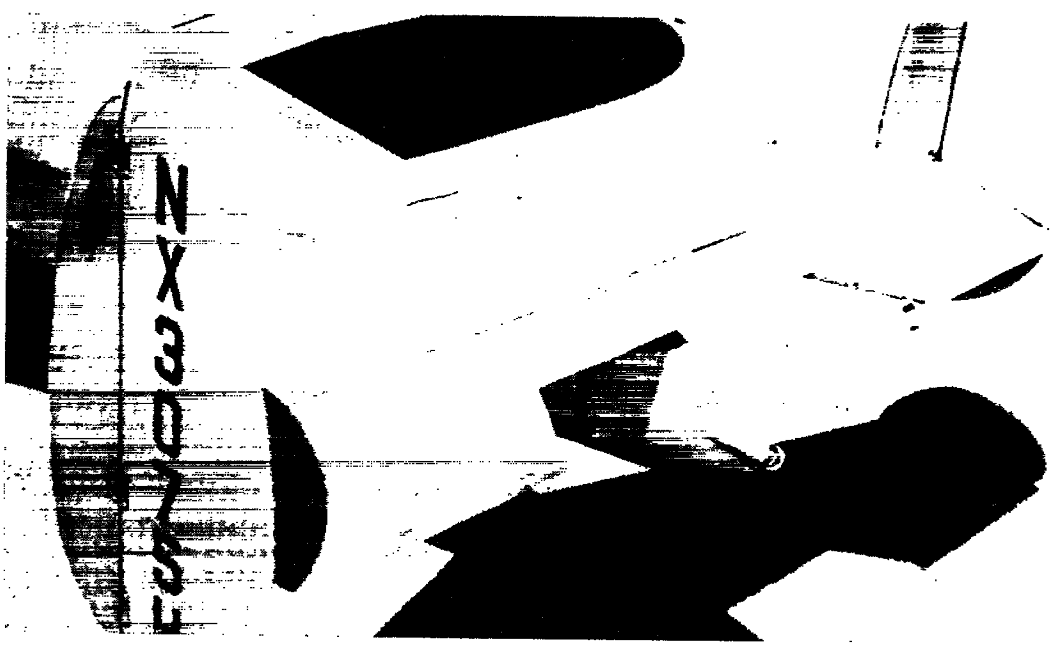


(c) View showing original fillet. L-90569

Figure 8.- Continued.

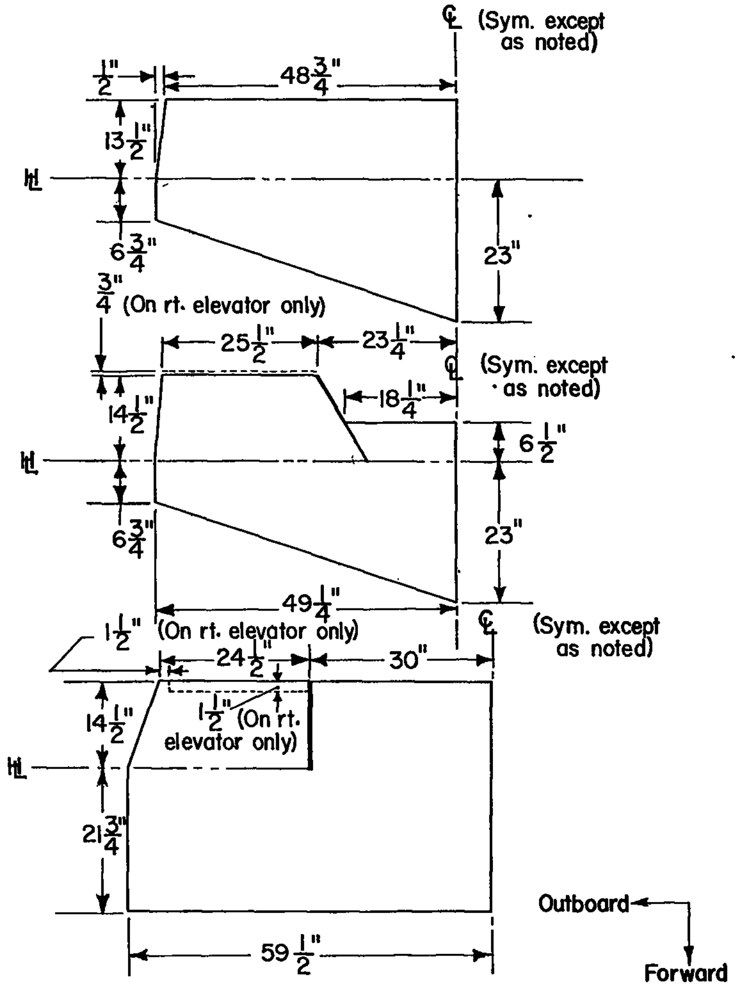


L-90570
(d) View showing enlarged fillet.



L-91673
(e) View showing modified tail 1.

Figure 8.- Concluded.

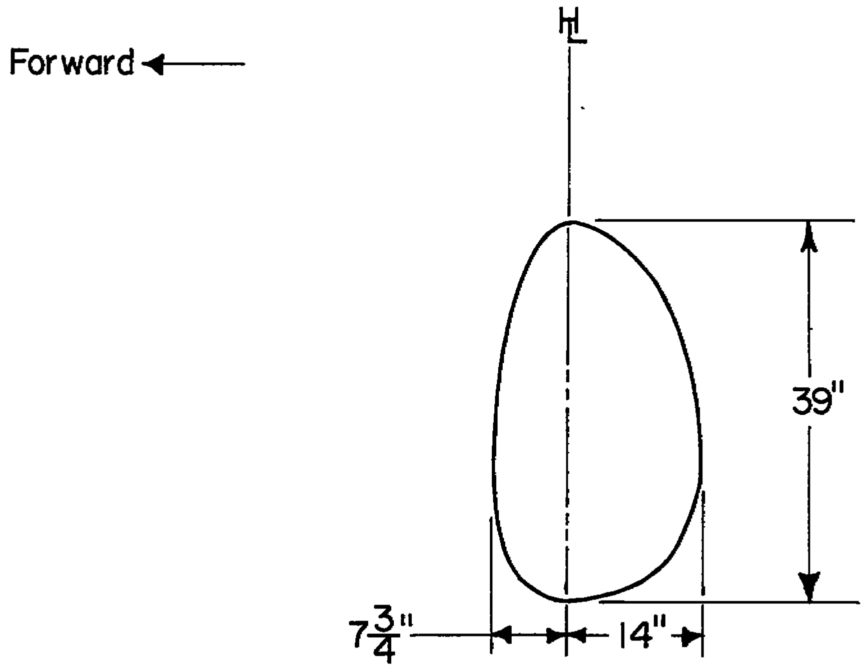


(a) Geometry of original horizontal tail.

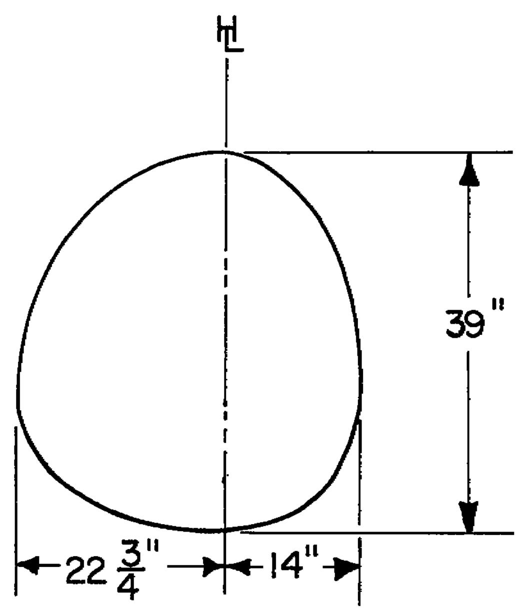
(b) Geometry of modified horizontal tail 1.

(c) Geometry of modified horizontal tail 2.

Figure 9.- Comparison of tail configurations used on Ercoupe airplane.

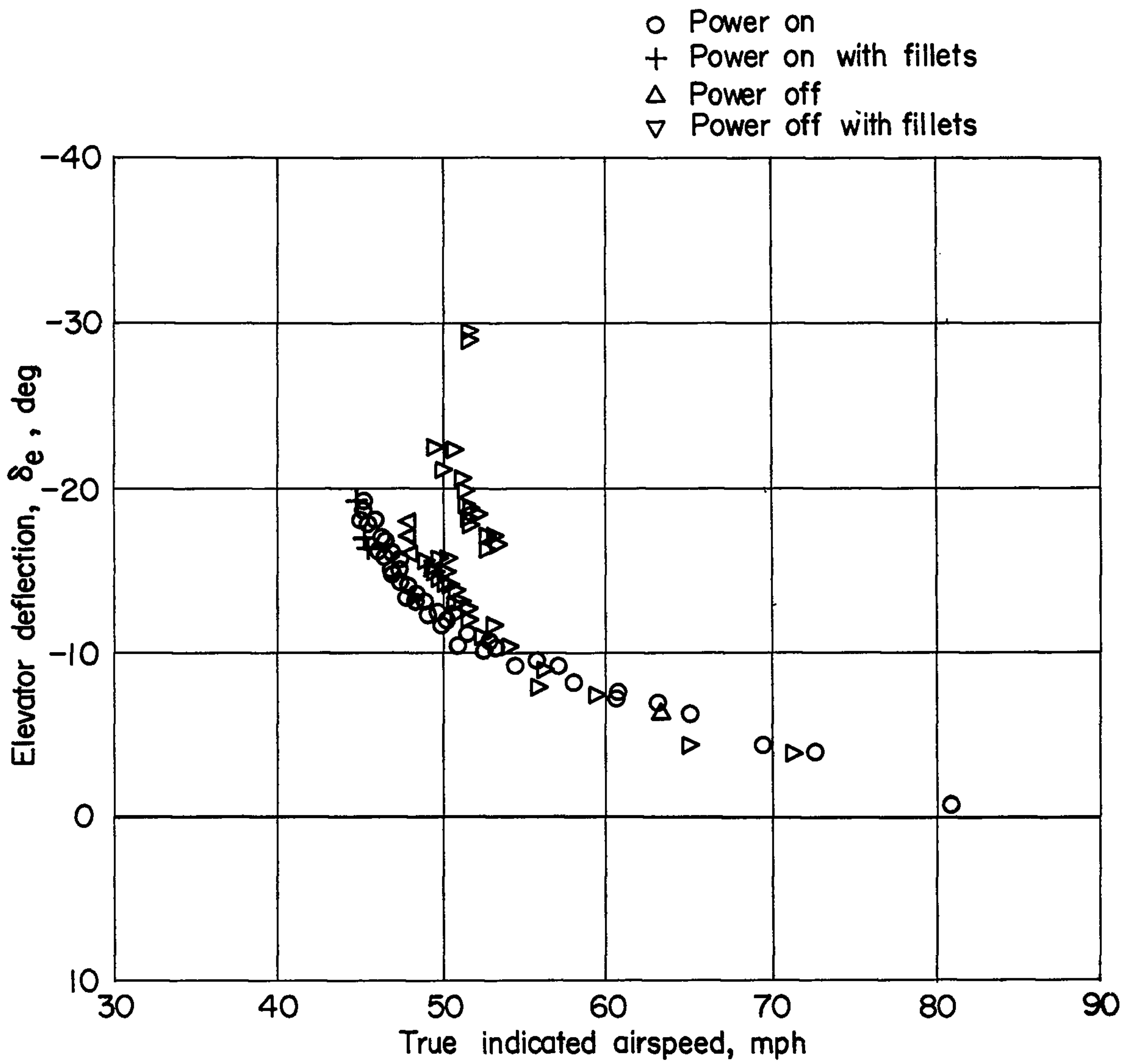


(d) Geometry of original vertical tail and modified vertical tail 1.



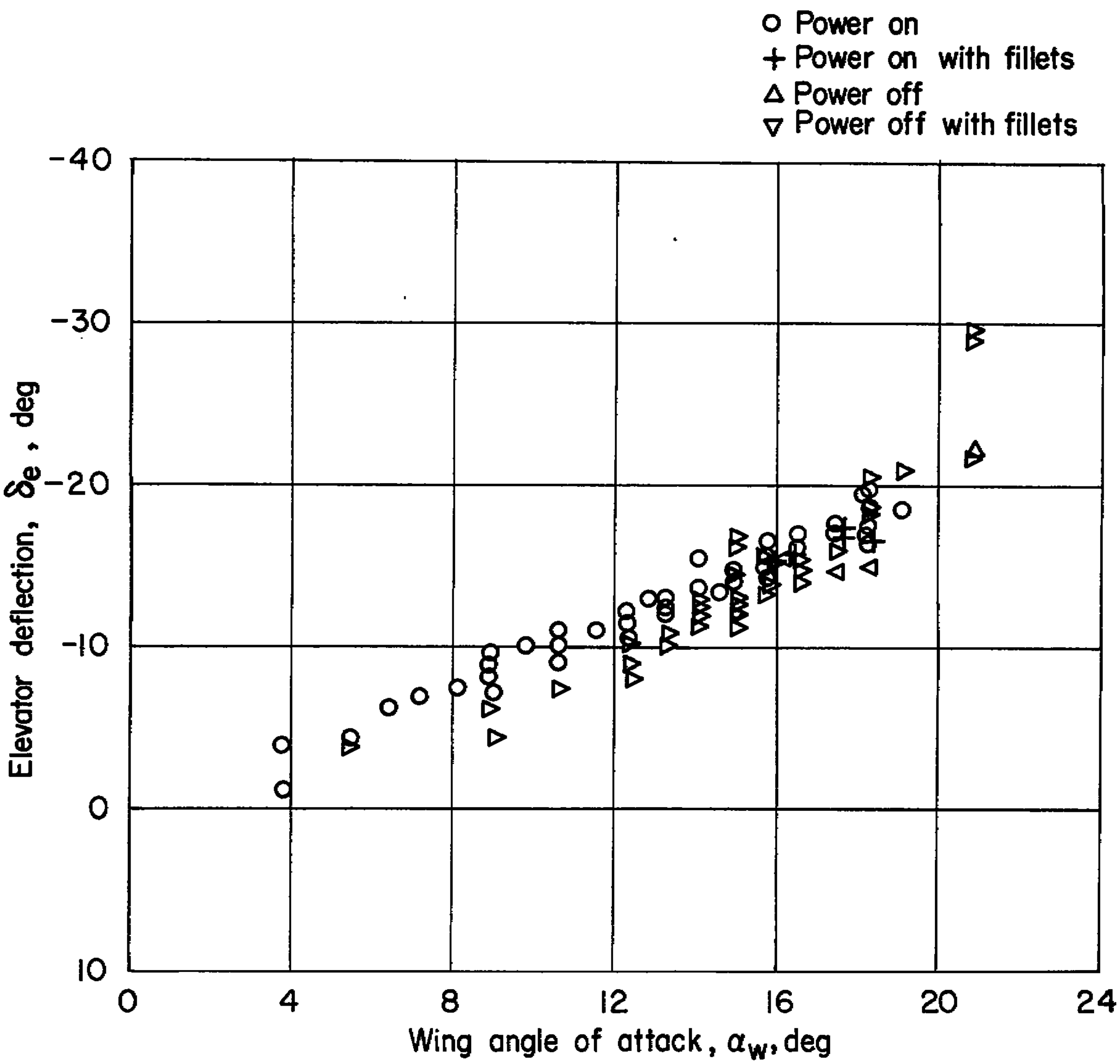
(e) Geometry of modified vertical tail 2.

Figure 9.- Concluded.



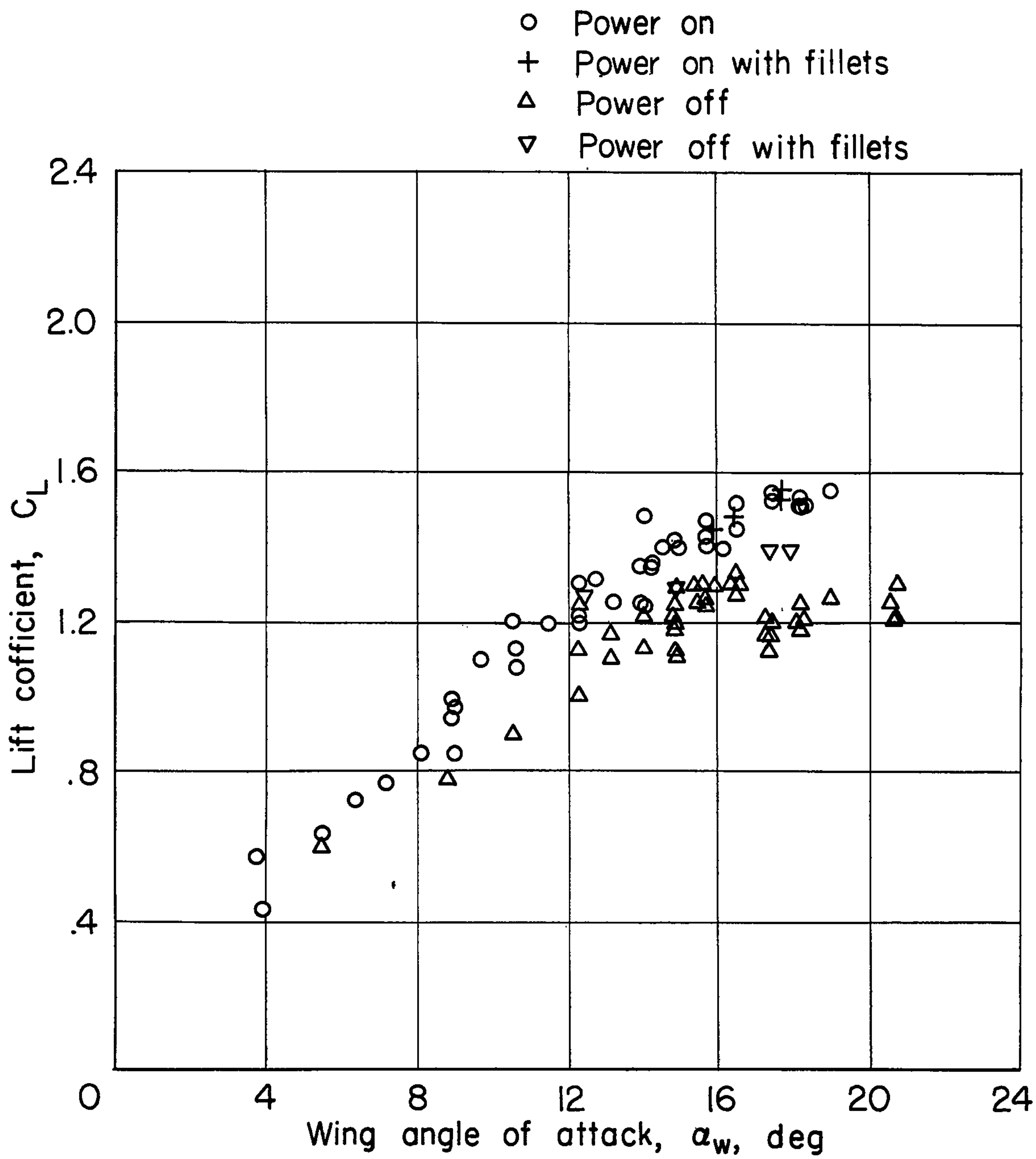
(a) Elevator deflection δ_e versus true indicated airspeed.

Figure 10.- Flight-test data for Ercoupe airplane with modified horizontal tail 1.



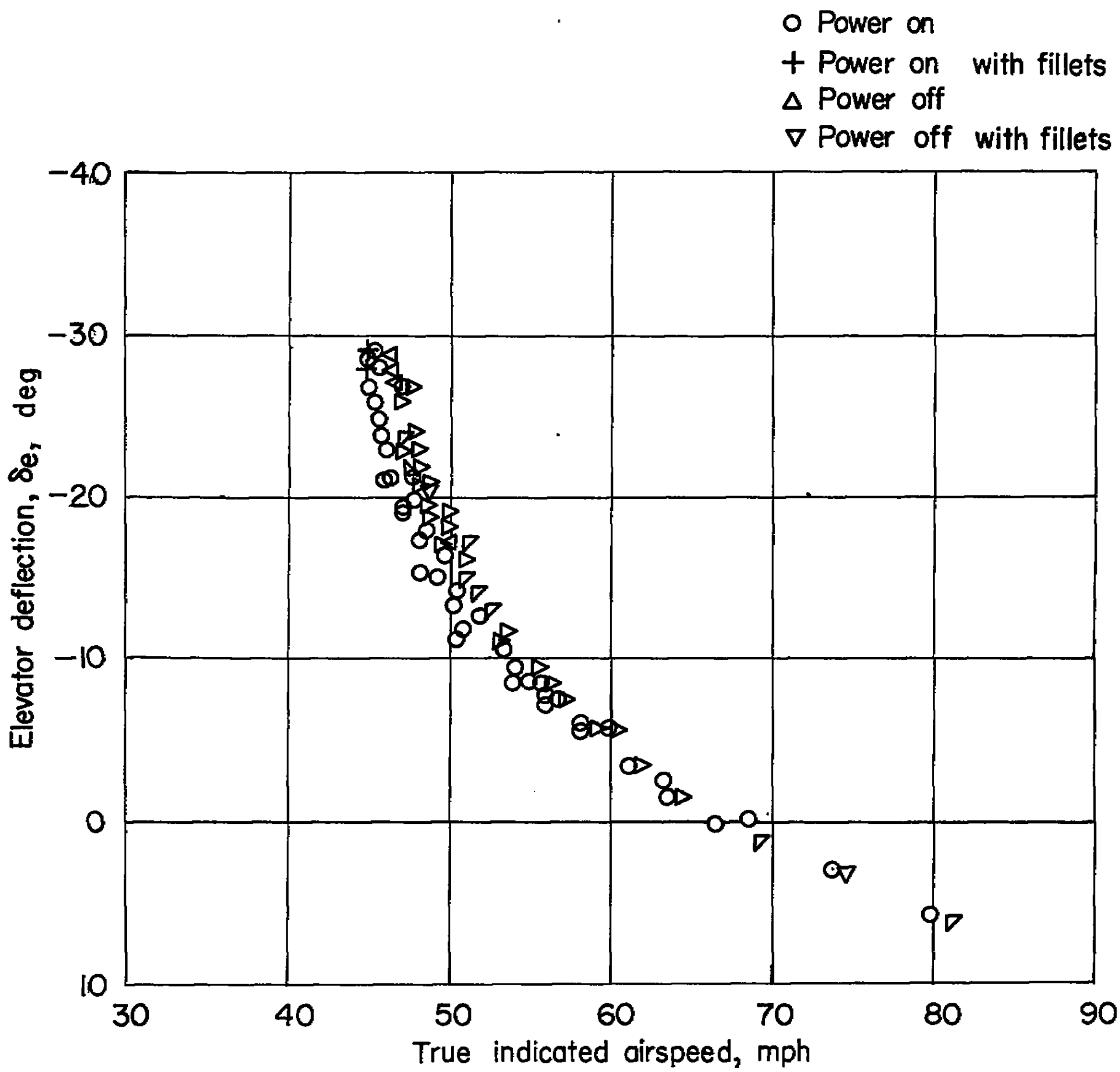
(b) Elevator deflection δ_e versus wing angle of attack α_w.

Figure 10.- Continued.



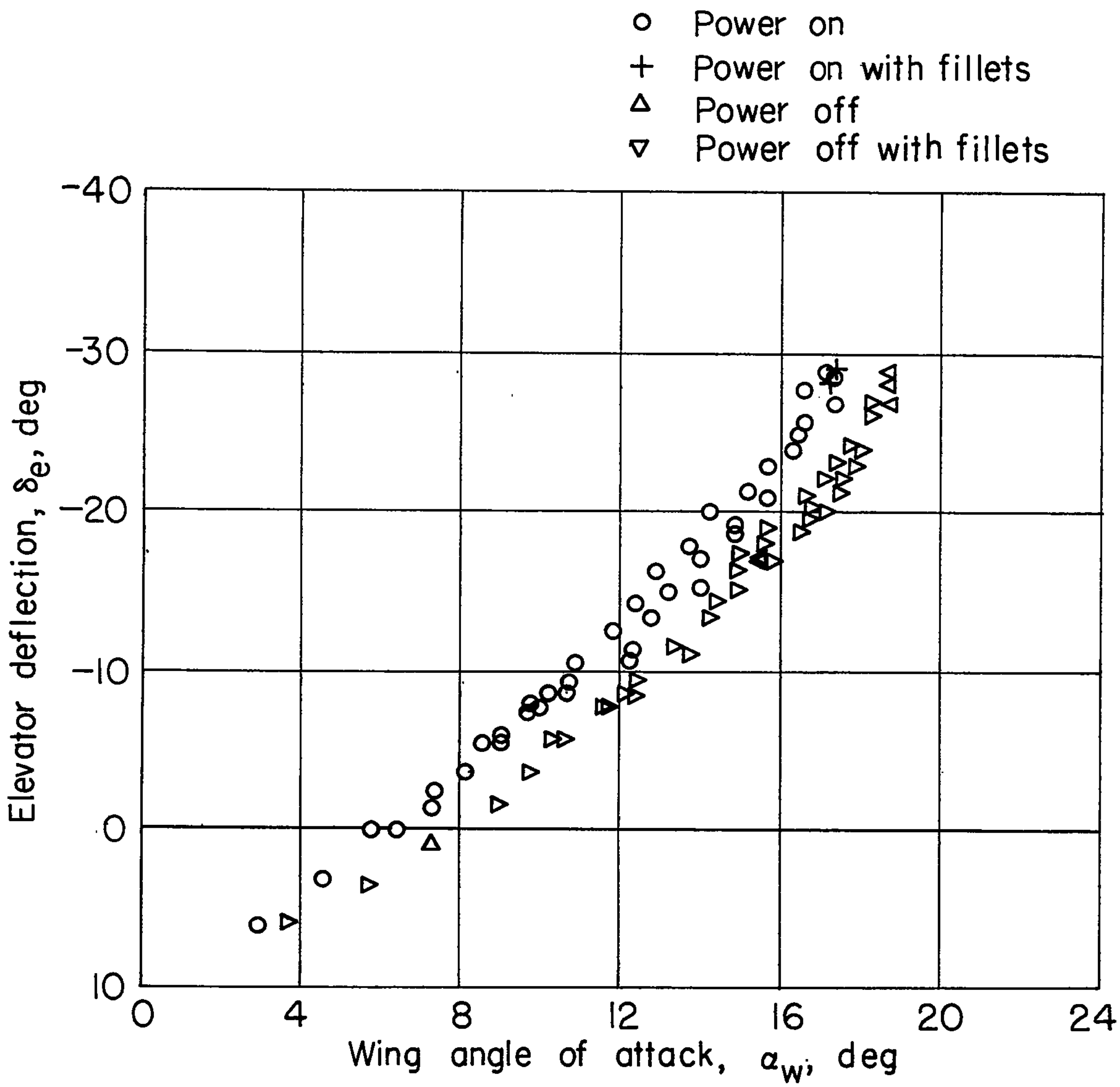
(c) Lift coefficient C_L versus wing angle of attack α_w.

Figure 10.- Concluded.



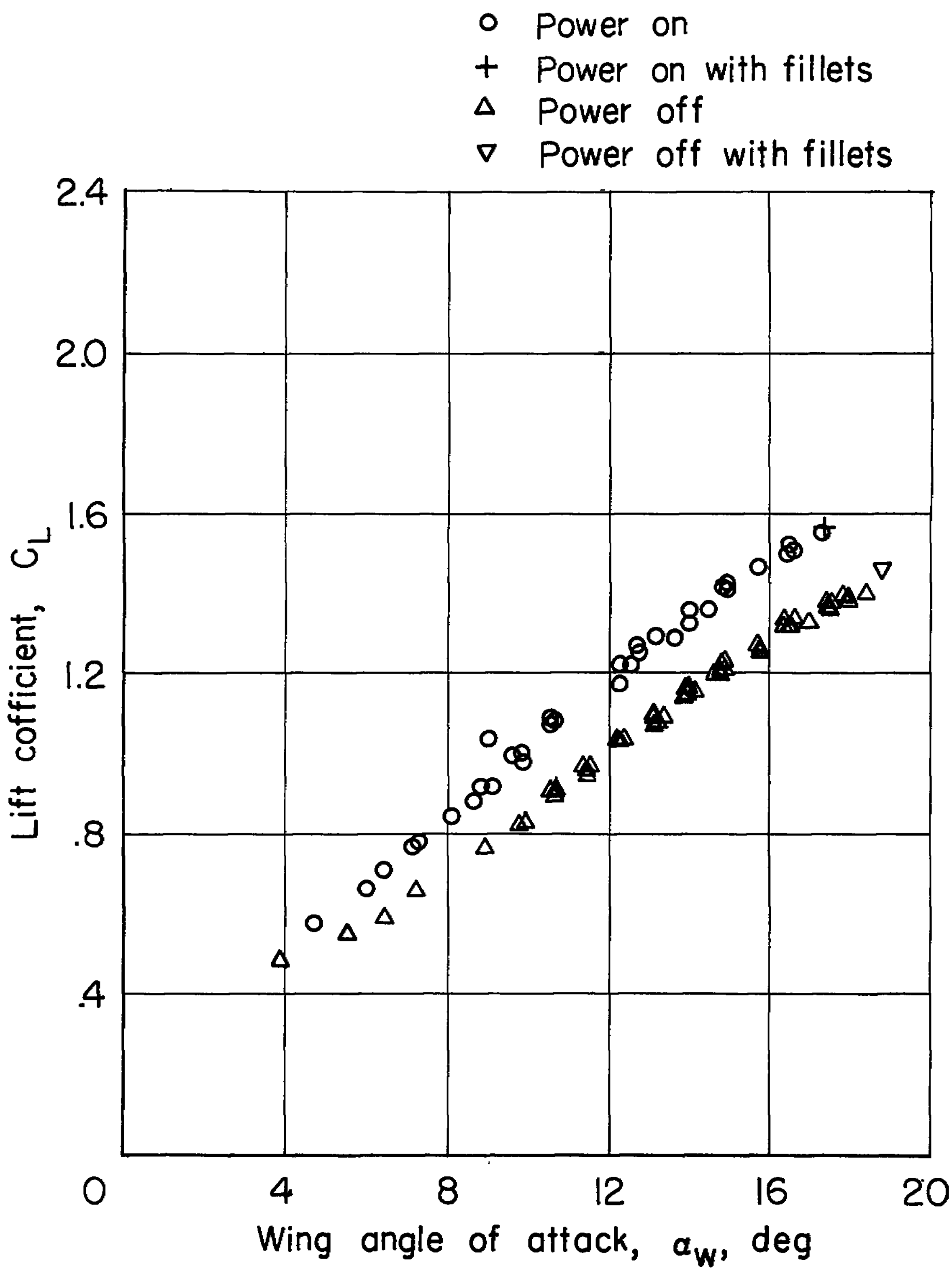
(a) Elevator deflection δ_e versus true indicated airspeed.

Figure 11.- Flight-test data for Ercoupe airplane with modified horizontal tail 2.



(b) Elevator deflection δ_e versus wing angle of attack α_w.

Figure 11.- Continued.



(c) Lift coefficient C_L versus wing angle of attack α_W.

Figure 11.- Concluded.

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